Risk Modeling Foundations Masterclass

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What to expect from this *Masterclass*?

- Learn how MATLAB can help solve key challenges in Risk
- Examples to get you started with MATLAB today
- Tips for enhancing productivity using new features
What are the key challenges in Risk Management?

- Ever-changing regulatory requirements:
  - Basel II, Basel III, Basel IV
  - Solvency II
  - DFAST, CCAR, IFRS9/CECL
  - FRTB

- Rapidly evolving technology:
  - Data analytics
  - Big data
  - Machine learning

- Cost and time efficiency:
  Align with business goal while being cost and time efficient

- Scaling pains:
  Difficulty moving models to production
Our examples for today

1. Value at Risk (VaR) estimation and backtesting

2. Modeling and stress testing of consumer credit default probabilities

3. Credit copula simulation and backtesting
Example 1: VaR Estimation and Backtesting

Goal: Estimate VaR using different methods and backtest the estimations

Scale up analysis to include Expected Shortfall estimation
Are you Backtesting Expected Shortfall (ES)?
*New* in the Risk Management Toolbox R2017b

- **VaR Backtests ask:**
  - **How many times** was the VaR exceeded?
  - Were the exceedances **independent**?

- **ES Backtests ask:**
  - **By how much** was the VaR exceeded?
  - **How severe** is this exceedance?

<table>
<thead>
<tr>
<th>Date</th>
<th>Return</th>
<th>VaR</th>
<th>ES</th>
</tr>
</thead>
<tbody>
<tr>
<td>26-Jul-16</td>
<td>-1.308</td>
<td>1.078</td>
<td>1.364</td>
</tr>
<tr>
<td>28-Sept-16</td>
<td>-2.051</td>
<td>1.110</td>
<td>1.404</td>
</tr>
<tr>
<td>2-Nov-16</td>
<td>-1.353</td>
<td>1.218</td>
<td>1.541</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Severity Ratio</th>
<th>Observed (-Return/VaR)</th>
<th>Expected (ES/VaR)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Observed</td>
<td>Expected</td>
</tr>
<tr>
<td></td>
<td>Average: 1.39</td>
<td>Average: 1.27</td>
</tr>
</tbody>
</table>

Is there a big difference between 39% and 27%?

See this in action at the Demo Station!
Are you Backtesting Expected Shortfall (ES)?

*New* in the Risk Management Toolbox R2017b

Use multiple Expected Shortfall Backtesting tools for assessing ES models

- **Table-Based Tests**
  - Use pre-computed critical values
  - Don’t require distribution information
  - Simple to use

- **Simulation-Based Tests**
  - Critical values are simulated
  - Distribution assumptions required

**Tip:** Perform tests independently or all at once using `esbacktest` or `esbacktestbysim`
Summary: VaR Estimation and Backtesting

**Goal:** Estimate VaR using different methods and backtest the estimations

**Key Takeaways:**

- Interactively analyze data and prototype ideas
- Leverage built-in functionality for fast development
- Span the model full model development & testing workflow
- Expected Shortfall framework essential for FRTB compliance

**Tip:** Working with timeseries data? Use timetables for improved efficiency
Example 2: Consumer Credit Default Probabilities

Goal: Fit a logistic regression model of default rates
Stress test the model under different economic scenarios

<table>
<thead>
<tr>
<th>ID</th>
<th>ScoreGroup</th>
<th>YOB</th>
<th>Default</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Low Risk</td>
<td>1</td>
<td>0</td>
<td>1997</td>
</tr>
<tr>
<td>1</td>
<td>Low Risk</td>
<td>2</td>
<td>0</td>
<td>1998</td>
</tr>
<tr>
<td>1</td>
<td>Low Risk</td>
<td>3</td>
<td>0</td>
<td>1999</td>
</tr>
<tr>
<td>2</td>
<td>Medium Risk</td>
<td>1</td>
<td>0</td>
<td>1997</td>
</tr>
<tr>
<td>2</td>
<td>Medium Risk</td>
<td>2</td>
<td>0</td>
<td>1998</td>
</tr>
<tr>
<td>2</td>
<td>Medium Risk</td>
<td>3</td>
<td>0</td>
<td>1999</td>
</tr>
<tr>
<td>12</td>
<td>High Risk</td>
<td>1</td>
<td>0</td>
<td>1998</td>
</tr>
<tr>
<td>12</td>
<td>High Risk</td>
<td>2</td>
<td>0</td>
<td>1999</td>
</tr>
<tr>
<td>12</td>
<td>High Risk</td>
<td>3</td>
<td>0</td>
<td>2000</td>
</tr>
</tbody>
</table>

Tip: Use the new Contextual Hints in Live Editor to speed up prototyping
tall arrays

Tip: Working with big data? Use tall for data that is too big to fit in memory

- New data type as of R2016b
- Lots of observations (hence “tall”)
- Looks like a normal MATLAB array
  - Supports numeric types, tables, datetimes, strings, etc…
  - Supports several hundred functions for basic math, stats, indexing, etc.
  - Statistics and Machine Learning Toolbox support
    (clustering, classification, etc.)
Example 2: Consumer Credit Default Probabilities

Compare Logistic Regression Model to Cox Proportion of Hazards Model

Semi-parametric:
- Baseline hazard rate (PD curve) has a flexible shape that can match data patterns

Supports time-dependent predictors
- Macro-economic variables can be used as predictors
- Model can be used for stress testing
Summary: Consumer Credit Default Probabilities

Goal: Prototype a logistic regression model of default rates

Key Takeaways:

• Work effectively with large out-of-memory datasets
• Transparency of functions satisfies model validation teams
• Flexibly model lifetime expected credit loss (ECL) using various models and compare results

Tip: Use varfun to apply functions to variables in a table
**Example 3: Credit Portfolio Simulation using Copulas**

**Goal:** Calculate credit risk of credit portfolio with correlated defaults
Share model via an Excel front-end

**Portfolio of Loans**

Credit Risk of Loan 1

- **EL₁ (Expected Loss)**
- **EAD₁ (Exposure At Default)**
- **PD₁ (Probability of Default)**
- **LGD₁ (Loss Given Default)**

Credit Risk of Loan N

- **ELₙ**
- **EADₙ**
- **PDₙ**
- **LGDₙ**

Assume any dependencies?
What if we lived in the world with independent default?

<table>
<thead>
<tr>
<th>Loan</th>
<th>EAD</th>
<th>PD</th>
<th>LGD</th>
<th>EL</th>
<th>95% VaR</th>
<th>95% CVaR</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>20</td>
<td>0.06</td>
<td>0.35</td>
<td>0.42</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>2</td>
<td>30</td>
<td>0.06</td>
<td>0.35</td>
<td>0.63</td>
<td>10.5</td>
<td>10.5</td>
</tr>
</tbody>
</table>

Portfolio Level

- **PD₁**: 94% Default, 6% Non-default
- **PD₂**: 94% Default, 6% Non-default

Correlation = 0
What if correlations ($\rho$) among PDs ≠ 0?

No. of Loans (n) | No. of $\rho$ [0.5 * n * (n-1)]
--- | ---
2 | 1
3 | 3
4 | 6
10 | 45
100 | 4,950
1,000 | 499,500
2,000 | 1,999,000
Why use a copula?

Reduce a large correlation matrix to a smaller one…

$$Prob\ State\ Change = \beta_1 F_1 + \beta_2 F_2 + \cdots + \beta_N F_N + \epsilon$$

**Factor Exposures**

<table>
<thead>
<tr>
<th>ID</th>
<th>Utilities</th>
<th>Financials</th>
<th>Oil &amp; Gas</th>
<th>Tech</th>
<th>(\epsilon)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0%</td>
<td>25%</td>
<td>5%</td>
<td>55%</td>
<td>15%</td>
</tr>
<tr>
<td>2</td>
<td>40%</td>
<td>0%</td>
<td>20%</td>
<td>0%</td>
<td>40%</td>
</tr>
<tr>
<td>3</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>70%</td>
<td>30%</td>
</tr>
</tbody>
</table>

**Factor Correlations**

<table>
<thead>
<tr>
<th>Factor</th>
<th>Utilities</th>
<th>Financials</th>
<th>Oil &amp; Gas</th>
<th>Tech</th>
</tr>
</thead>
<tbody>
<tr>
<td>Utilities</td>
<td>1.00</td>
<td>0.823</td>
<td>0.720</td>
<td>0.833</td>
</tr>
<tr>
<td>Financials</td>
<td>0.823</td>
<td>1.00</td>
<td>0.808</td>
<td>0.677</td>
</tr>
<tr>
<td>Oil &amp; Gas</td>
<td>0.720</td>
<td>0.808</td>
<td>1.00</td>
<td>0.635</td>
</tr>
<tr>
<td>Tech</td>
<td>0.833</td>
<td>0.677</td>
<td>0.635</td>
<td>1.00</td>
</tr>
</tbody>
</table>
Deploying Applications with MATLAB

1. MATLAB Desktop

2. MATLAB Compiler

3. MATLAB Runtime

Toolboxes

MATLAB Application

.xla

End-User Machine
Example 3: Credit Portfolio Simulation using Copulas

Goal: Calculate credit risk of credit portfolio with correlated defaults
Share model via an Excel front-end

Key Takeaways:
• Built-in functionality for simulating correlated defaults in a few commands
• Quickly take a model from prototype to production

Tip: Need to share your models? MATLAB Compiler allows you to deploy MATLAB models royalty-free.
MATLAB’s solutions

Ever-changing regulatory requirements
- Customize models easily to respond to changing regulations
- Document as you go

Rapidly evolving technology
Easily try new approaches using libraries of pre-built functions

Cost and time efficiency
- Speed up your development cycle with high-level functionality
- Flexible modeling overlaid with interactive workflows

Scaling pains
Move models from prototype to production without recoding
Workflow and Toolboxes

Access
- Files
- Databases
- Datafeeds

Research and Quantify
- Data Analysis and Visualization
- Financial Modeling
- Application Development

Share
- Reporting
- Applications
- Production

MATLAB
- Trading
- Spreadsheet Link
- Database
- Datafeed
- Financial Instruments
- Financial
- Statistics
- Risk Management
- Econometrics
- Optimization

Toolboxes
- MATLAB Distributed Computing Server
- MATLAB Compiler
- MATLAB Compiler SDK
- MATLAB Production Server

MATLAB Report Generator

Parallel Computing
- MATLAB
Want to learn more?

Contact us!

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